How Much (How Little?) Did We Know About Sextupole Contents in Booster Magnets?

Sho Ohnuma

June 11, 2003

Did we want to know? Yes!

Chromaticities (call it ξ_H and ξ_V) are the best source of information on sextupole contents in a ring ------- Agreed .

Reliable values of ξ come from reliable values of tunes (and $\Delta p/p$).

Francois is now working on an improved algorithm for tune measurements.

But let's assume that the existing measurements are not "too bad":

ξ_H is negative and "large", ξ_V is positive and "small",

both at high and low energies (with or without doglegs) if correction sextupole currents are zero.

1. High energies, Bob Peters (ca. 1973-74), see TM-507

   $\xi_H = -17$ and $\xi_V = +4$

2. Low energies (400 MeV? in 1990), Ray Tomlin (quoted by Weiren Chou in his memo to me, 2001, with or without doglegs?)

   $\xi_H = -15$ and $\xi_V = +4$ (ISEXTS=0 and ISEXTL=5A)

History

1. Stan Snowdon, TM-156 (1969)

   For $\xi = 0$ in both directions, we should have

   k_2 (= B"/Bρ in m^{-3}) = 0.01488 (F) and -0.02615 (D)

   According to MAD, these values indeed give $\xi = 0$ for the design lattice.

   Note: Actually, MAD says (0.0166, -0.0276) for zero Chromaticities.

2. Measured sextupole field in the body of magnets

   Bob Peters in 1969. See FN-192 (1969) and TM-405 (1973).

   2.a From the attached figures, Weiren (and others?) extracted

   k_2 = 0.026 (F) and –0.021 (D): straight lines between 0" and 1".

   For the design lattice (no doglegs), MAD says

   ξ_H = + 10.75 and ξ_V = - 4.78

   2.b I tried to draw tangential lines at x = 0 in the same figure.

   k_2 = + 0.025 (F) and - 0.027 (D)

   Then, MAD says ξ_H = + 8.26 and ξ_V = - 2.17 for the design lattice.

   2.c Stan Snowdon calculated (half analytical, half numerical) tunes between $\Delta p/p$ = - 0.018 and + 0.018 (see FN-192).

   Using tunes at $\Delta p/p$ = - 0.002, 0.,+ 0.002, I find

$\xi_H = +\ 9.25$ and $\xi_V = -\ 2.50$ at $\Delta p/p = 0$.

Note: Stan says this is with the measured body field and "design" end field.

I believe it is safe to say that the body sextupole field in booster magnets give positive and "large" ξ_H and negative and "small" ξ_V for the design lattice.

Note: Stan's values for chromaticities, 2.c, include the "design" Endpack field. I have no idea what it is.

According to FN-192 by Stan Snowdon, endpacks were then designed to recover zero chromaticities. They were built and measured by Bob Peters, FN-192 says. Bob Peters says the measurement data are "lost", that is, nobody knows where they are.

Stan Snowdon in FN-192 calculates tunes between $\Delta p/p = -0.018$ and $+0.018$ again using the measured field, body and ends.

From tunes at $\Delta p/p = -\ 0.002,\ 0,\ +\ 0.002$, I find

$$\xi_H = -\ 9.75 \quad \text{and} \quad \xi_V = +\ 9.50 \quad \text{at } \Delta p/p = 0.$$

As Stan says, endpacks are overcompensating the body field. He then modified the endpack design such that tunes are more or less flat within the momentum range under consideration.

Question is: Are the present endpacks the ones before redesign or after the redesign? Does anyone know?

Note: Why did Stan considered such a large momentum range, $\Delta p/p = -\ 0.018$ to $+\ 0.018$? Did he and others believe that Booster could have such a large momentum acceptance?

Endpacks as thin-lens multipole

Since we knew nothing about the endpack field, we assumed that the endpack contribution can be treated as a thin-lens sextupole. This may not be justified.

A. High Field

A.1 If k_2(body) is (0.026, -0.021), we ***should*** have (according To MAD)

(k_2L) = <u>- 0.0144 (F)</u> and - 0.0087 (D)

If, on the other hand, $\xi_H = -17$ and $\xi_V = +4$ is true, we now ***must*** have

(k_2L) = <u>- 0.0435 (F)</u> and - 0.0042 (D)

A.2 If k_2(body) is (0.025, -0.027), we ***shoud*** have

(k_2L) = <u>- 0.0136 (F)</u> and + 0.0007 (D)

If, on the other hand, $\xi_H = -17$ and $\xi_V = +4$ is true, we now ***must*** have

(k_2L) = <u>- 0.0427 (F)</u> and + 0.0052

Tom Collins and others (including me) therefore concluded (but didn't say so in writing) that "F-magnet endpacks are wrong."

Note: Was this conclusion justified?

This may not really contradict with the statement by Weiren that "F-magnets are perfect but D-magnets are not." for several reasons:

1. Bob Peter's field measurement is at high energies, presumably dc ,while Weiren is talking about low energy chromaticities and low energy sextupole field.

2. We represented endpacks as thin-lens sextupoles while Weiren uses, I believe, average sextupole distributed uniformly in the magnet body to represent the combined body-endpack field.

3. Even at high energies, lattice may be quite different from the design lattice.
4. Bob's measured chromaticities are not correct.

5. MAD does not treat combined magnets properly.
   (I have divided each magnet into 16 pieces.)

6. and many others …

B. Low Field

Since I didn't know anything about low field sextupole field in 2000, I simply used the same body field (k_2) that was used for high field. This cannot be right but how bad it is, I don't know.

I also assumed that chromaticities are (Ray Tomlin in 1990)

$$\xi_H = -15 \quad \text{and} \quad \xi_V = +4 \quad \text{with ISEXTL} = 5\text{A}.$$

I am not sure if this measurement was done with or without doglegs, but let me assume here that it was done **with**.

I use Sasha's MAD input file, V1.7, with doglegs as well as magnet tilts. Actually, I ignored magnet tilts entirely since they don't really affect the results. For example, with tilts: natural chromaticities are - 9.429 and - 7.409,

without tilts: - 9.430 and - 7.412.

Note: For zero chromaticities, with doglegs, we should have k_2 = + 0.018 (F) and – 0.030(D) for the body (and no endpack).

B.1 If k_2(body) is (0.026, - 0.021), we now ***must*** have

(k_2L) = - 0.0387 (F) and -0.0077 (D)

B.2 If k_2(body) is (0.025, - 0.027), we now ***must*** have

(k_2L) = -0.0379 (F) and + 0.0017 (D)

Results are not too different from the high field results, A.1 and A.2.

So, what went wrong?

We need

1. Better measurements of chromaticities with the refined FFT algorithm.

2. We need ac measurements of sextupole field at high field.